# Limits of integrating taxation in real option theory

## Caren Sureth[a], Rainer Niemann[b]

[a]*University of Bielefeld, Department of Economics,*
*P.O. Box 10 01 31, D-33501 Bielefeld, Germany,*
*phone: +49 521 106 5113,*
*email: csureth@wiwi-uni.bielefeld.de*
[b]*University of Tübingen, Department of Economics,*
*Mohlstrasse 36, D-72074 Tübingen, Germany,*
*phone: +49 7071 297 8184,*
*email: rainer.niemann@uni-tuebingen.de*

## Extended Abstract

It is well known in the theory of capital budgeting that taxes may have a significant impact on investment decisions. Since real options are now widely accepted for assessing investment projects in financial theory as well as in business practice, it is straightforward to integrate taxation into real option-based models. By doing so, it is possible to derive a post-tax investment rule and to identify tax-induced investment distortions. Consequently, real options literature has been enriched by some recent publications on taxational issues [e.g., Mauer and Ott (1995), Harchaoui and Lasserre (1996), Alvarez and Kanniainen (1997), Jou (2000), Pennings (2000), Agliardi (2001)]. Nevertheless, neither the pre-tax models nor the integration of taxes follow a unified pattern. Therefore, these approaches are not applicable to draw general conclusions concerning the influence of taxation on investment behavior.

Our objective is to analyze the integration of taxes under risk neutrality and risk aversion and to quantify tax effects. At first, this requires the fundamental decision between two approaches: either dynamic programming (DP) or contingent claims analysis (CCA).

This raises the questions if both approaches permit the integration of taxes, if they yield equivalent investment rules, and – as a consequence – if a superior approach can be identified.

Starting with the risk neutrality assumption and using a perpetual option to invest it can be shown that both DP and CCA permit the integration of taxes. Despite their different assumptions, DP and CCA yield identical pre-tax and post-tax investment thresholds under risk neutrality. The reason for this equivalence is that the discount rate does not carry a risk premium so that both approaches do not rely explicitly on particular risk preferences. The impact of taxation can be demonstrated using simple examples with real world tax systems indicating that the critical investment threshold may easily double compared to the tax-free case.

In contrast, risk aversion largely complicates the analysis because there are severe problems in determining an adequate risk-adjusted discount rate, even in the pre-tax case. Strictly speaking, a sophisticated capital market model determining a risk-adjusted discount rate after taxes is needed to solve investment problems under risk aversion correctly. Such a model does not yet exist and cannot be expected in the next several years. As a heuristic approximation, it could be recommended to employ an exogeneously given discount rate and to ensure the applicability of real option models. Mis-estimating the risk premium may induce a less severe deviation from the correct investment threshold than neglecting taxation.

According to option pricing theory, in CCA, it is possible to derive an investment rule without referring to individual utility functions by constructing a risk-free hedge portfolio. Under risk aversion, this result is restricted to cases with a dividend rate unaffected by risk which may be considered unlikely for long-term investment projects. Unfortunately, real option theory imposes additional difficulties, but does not offer additional insights in isolating taxational effects.

Using an individual time preference rate under risk aversion, our DP approach endogenizes investors' risk preferences by employing their utility functions. In this case, DP permits an explicit investment threshold without taxation. Although this procedure

requires quite restrictive assumptions and limits the analysis to specific classes of utility functions, investors are enabled to gain important support for investment decisions. After taxes, DP as well as CCA fail to reach general solutions due to the investment problem's non-linearity.

These pre-tax and post-tax problems reveal the restrictions of the integration of taxes in capital budgeting as well as the limitations of the real option approach itself. Both DP and CCA are limited to a rather restrictive set of assumptions and furthermore, they lose their equivalence under risk aversion.

CCA relies heavily on the availability of market data whereas the DP-approach substitutes individual parameters for market information. By doing so, DP allows analytical solutions of the emerging investment problems at least in special cases. Of course, these solutions' meaningfulness is limited to particular investment projects and cannot be generalized. In contrast, applicability of CCA-based solutions would be much more general but would require a still unknown model of capital market equilibrium. Obviously, there is a trade-off between solubility and generality leading to the conclusion that there is no superior one-fits-all approach in real option theory. The investor has to choose the approach in accordance with the underlying investment problem. Whereas commodity-related projects permit the application of CCA, non-traded or non-replicable projects might require DP using non-generalizable investor-specific data.

Apart from solving the emerging investment problems integrating taxation might be interesting from a tax policy perspective. Neutral tax systems, i.e., tax systems that do not distort the investment decision prevent funds from being invested in investment projects that do not earn their cost of capital.

Applying real option approaches, either DP or CCA, investment neutrality of a cash flow tax and the Johansson-Samuelson-tax can be proved under risk neutrality [cf. Niemann (1999), Sureth (2002)]. Uncertainty and irreversibility do not violate the neutrality property of these tax systems. In contrast, under risk aversion, proving a tax system's neutrality requires further assumptions concerning the project's life, its cash flows and depreciation allowances in case of DP and the distribution of the risk premium among

the growth parameter and the dividend rate in CCA. Nevertheless, it is possible to derive neutral tax systems under risk aversion without explicit investment thresholds. This is demonstrated by equating the pre-tax and the post-tax investment problems using the DP approach. Neutral tax systems under risk aversion depend on the investor's utility function and thus cannot be generalized.

Although investment decisions under risk aversion supported by the real option approach cannot be attributed to a single, all-embracing investment rule, DP and CCA significantly enrich capital budgeting. One problem of traditional models remains: neglecting taxation may induce wrong decisions and a waste of funds.

## References

Agliardi, E., 2001. Taxation and Investment Decisions: A Real Option Approach. Australian Economic Papers 40, 44-55.

Alvarez, L.H.R., Kanniainen, V., 1997. Valuation of Irreversible Entry Options under Uncertainty and Taxation. CES Working Paper No. 144, University of Munich.

Black, F., Scholes, M.S., 1973. The Pricing of Options and Corporate Liabilities. Journal of Political Economy 81, 637-654.

Boadway, R.W., Bruce, N., 1984. A General Proposition on the Design of a Neutral Business Tax. Journal of Public Economics 24, 231-239.

Bogue, M.C., Roll, R., 1974. Capital Budgeting of Risky Projects with "Imperfect" Markets for Physical Capital. Journal of Finance 29, 601-613.

Brennan, M.J., Schwartz, E.S., 1985. Evaluating Natural Resource Investments. Journal of Business 58, 135-157.

Brown, E.C., 1948. Business-Income Taxation and Investment Incentives. In: Metzler, L.A. et al. (Eds.), Income, Employment and Public Policy, Essays in Honor of A.H. Hansen. Norton, New York, pp. 300-316.

Constantinides, G.M., 1980. Admissible Uncertainty in the Intertemporal Asset Pricing Model. Journal of Financial Economics 8, 71-86.

Cox, J.C., Ross, S.A., 1976. The Valuation of Options for Alternative Stochastic Processes. Journal of Financial Economics 3, 145-166.

Dixit, A.K., 1989. Entry and Exit Decisions under Uncertainty. Journal of Political Economy 97, 620-638.

Dixit, A.K., Pindyck, R.S., 1994. Investment under Uncertainty. Princeton University Press, Princeton.

Fama, E.F., 1977. Risk-Adjusted Discount Rates and Capital Budgeting under Uncertainty. Journal of Financial Economics 5, 3-24.

Grenadier, S.R., Weiss, A.M., 1997. Investment in Technological Innovations: An Option Pricing Approach. Journal of Financial Economics 44, 397-416.

Harchaoui, T.M., Lasserre, P., 1996. Le choix de capacité comme l'exercice d'une option d'achat financière. Canadian Journal of Economics 29, 271-288.

Johansson, S.-E., 1969. Income Taxes and Investment Decisions, Swedish Journal of Economics 71, 104-110.

Jou, J.-B., 2000. Irreversible Investment Decisions under Uncertainty with Tax Holidays, Public Finance Review 28, 66-81.

Kazemi, H.B., 1991. The Multi-Period CAPM and the Valuation of Multi-Period Stochastic Flows. Journal of Financial and Quantitative Analysis 26, 223-231.

Lensink, R., Sterken, E., 2001. Asymmetric Information, Option to Wait to Invest and the Optimal Level of Investment. Journal of Public Economics 79, 365-374.

Mauer, D.C., Ott, S.H., 1995. Investment under Uncertainty: The Case of Replacement Investment Decisions, Journal of Financial and Quantitative Analysis 30, 581-605.

McDonald, R.L., Siegel, D.R., 1986. The Value of Waiting to Invest. Quarterly Journal of Economics 101, 707-727.

Merton, R.C., 1973a. An Intertemporal Capital Asset Pricing Model. Econometrica 41, 867-887.

Merton, R.C., 1973b. Theory of rational option pricing. Bell Journal of Economics 4, 141-183.

Moel, A., Tufano, P., 2002. When are Real Options Exercised? An Empirical Study of Mine Closings, Review of Financial Studies 15, 35-64.

Moretto, M., 2000. Irreversible Investment with Uncertainty and Strategic Behavior. Economic Modelling 17, 589-617.

Niemann, R., 1999. Neutral Taxation under Uncertainty - a Real Options Approach, Finanzarchiv Neue Folge 56, 51-66.

Panteghini, P., 2001. On Corporate Tax Asymmetries and Neutrality. German Economic Review 2, 269-286.

Pennings, E., 2000. Taxes and stimuli of investment under uncertainty, European Economic Review 44, 383-391.

Pindyck, R.S., 1991. Irreversibility, Uncertainty, and Investment. Journal of Economic Literature 29, 1110-1148.

Samuelson, P.A., 1964. Tax Deductibility of Economic Depreciation to Insure Invariant Valuations, Journal of Political Economy 72, 604-606.

Sureth, C., 2002. Partially irreversible investment decisions and taxation under uncertainty: A real option approach. German Economic Review 3, 185-221.