Real Options and Economic Depreciation

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Abstract

We describe a duality between the value of the real option to delay investment by one period and the expected economic depreciation over that period. One implication is that existing real options models, which treat depreciation as exogenous, are mis-specified.

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1. Real Options

Virtually all of the recent literature on micro-level investment uses the "real options" theory associated with Dixit and Pindyck (1994) among others. This theory emphasises the fact that, when irreversible real investments can be delayed, the "option" to delay may be valuable. In this case, the optimal timing of investment depends on the evolution of the real option value over time. Under quite general conditions, investment will be optimal as soon as the value of the option falls to zero, but not before then.

Let $V_{t,s}$ denote the expected value, estimated at time t, of an investment project undertaken at time $s \geq t$. This value is generally estimated as the discounted net cash-flow expected over the asset's lifetime, less the investment cost. The value at time t of the real option to delay investment for some period s is defined as:

$$\phi_{t,s} = I(V_{t,t+s} - V_{t,t}) \tag{1}$$

where I(.) is an indicator function such that $I(x) = x$ if $x > 0$, and otherwise $I(x) = 0$. This equation reflects the simple logic behind the real option to delay. If we currently expect the project to be more valuable in the event that investment is delayed one period, then $\phi > 0$ and the profit maximising strategy is to wait. Even if immediate investment would be profitable, so that $V_{t,t} > 0$, when the real option is positive we expect not investing immediately to be more profitable.

This observation lies at the heart of the real options theory, and has proven useful in many applications, including lease valuations (Grenadier, 1995), copper mining

(Cortazar and Casassus, 1998), and real estate (Capozza and Li, 1994). Theoretical advances have also continued, with recent contributions by Abel *et. al.* (1996) who incorporated partial reversibility of investment and Berk (1999) who offers a simple rule to account for interest rate uncertainty.

Despite its explicit focus on changes in the value of capital, all of the existing real options literature treats the depreciation of capital as at least exogenous (Dixit and Pindyck, 1994), if not zero (Capozza and Li, 1994). To address the significance of this assumption, we need to discuss the concept of economic depreciation.

2. Economic Depreciation

Engineers know how fast assets wear out, and what causes them to do so. Economic depreciation reflects both the engineering concept and a demand side effect. Hotelling's (1925) definition of economic depreciation incorporates the per-period change in two stocks: the service potential of the asset, and the value of that service potential. Economic depreciation is frequently used in regulatory economics, where depreciation is an important component of the permitted earnings for a regulated firm. For example, Crew and Kleindorfer (1992) recognise that rapid technological change will increase economic depreciation. By a minor change of notation to Crew and Kleindorfer's equation (3), we can write Hotelling's economic depreciation over some period s, denoted $D_{t,s}$ as:

$$D_{t,s} = V_{t,t} - V_{t,t+s} \tag{2}$$

where $V_{t,s}$ has the same interpretation as in (1) if the asset has not yet been installed. A simple comparison of (1) with (2) reveals a close relationship between real options and economic depreciation. Restricting attention to the case where depreciation is independent of whether the asset has actually been installed, our main result follows.

Theorem

When there is a positive value to the real option to delay, for any period, investment in an asset of infinite service potential, that value is exactly equal to the *negative of* the expected economic depreciation of that asset over that period.

The proof is trivial. Under the conditions of the theorem, $\phi_{t,s} = V_{t,t+s} - V_{t,t} > 0$, and, since the asset does not wear out, $D_{t,s}$ is independent of whether it is installed or not. Hence, the result is obvious by inspection.

3. Discussion and Implications

The theorem establishes a duality between economic depreciation and the real (delay) option value for an asset with infinite service potential. If the asset is expected to exhibit economic depreciation, a rational firm will not want to delay investment because the opportunity cost of the revenue lost over the forthcoming period is not compensated for in later periods. Of course, this does not necessarily mean that the firm will invest immediately either. Rather its optimal strategy is to invest now if $V_{t,t} > 0$ and to delay the project otherwise, provided there are no holding costs in doing so.

Suppose alternatively that $D_{t,s} < 0$, so that the value of the project is expected to appreciate over the relevant period. Now, the real option value is positive, indicating that delay is profitable. Moreover, our assumption of infinite service life implies that the expected growth in the value of the project is entirely due to demand side factors. Thus, relatively strong future demand for the asset's services makes delay more likely.

To summarise, projects for which demand is still growing are delayed, while those for which demand is expected to fall are undertaken immediately, provided they are currently profitable. Thus, a delayed project will eventually be undertaken when its value to the firm is maximised. If the value function is smooth and timing is assessed continuously, investment will occur as soon as expected economic depreciation becomes zero.

This analysis has two obvious implications for future work. First, it seems clear that the use of an exogenous rate of depreciation is inappropriate in real options models. The close connection that we have established between economic depreciation and real option values will persist even when the relevant asset has a finite service life since demand side effects will remain a component of economic depreciation. Indeed, unless service lives are unrelated to the volume of services produced, there is no justification for any exogenous component of depreciation in real options models.

Secondly, empirical models for estimating real option values can be reinterpreted as models for predicting economic depreciation. This is likely to prove useful in regulatory settings, such as those discussed by Crew and Kleindorfer (1992), where the estimation of economic depreciation is a difficult problem. The authors are currently addressing both of these issues in work in progress.

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