Policy Design as an Irreversible Investment Under Uncertainty: Norwegian Agriculture and the WTO

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Summary

This paper is concerned with the timing of an agricultural policy reform under uncertainty. The focus is on the opportunity cost of giving up the option to wait when implementing a policy reform. Including the option value in applied policy analysis can help explain why conventional analyses may find observed policies to be Pareto-inferior. Furthermore, it explains why otherwise profitable policy reforms may be delayed. The theoretical model is applied to Norwegian agricultural policy anticipating a prospective WTO agreement. It is argued that the option value should be incorporated into applied policy analysis when high uncertainty prevails.

Keywords: Option value, Policy reform, WTO, Norway, Uncertainty

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1. Introduction

Applied agricultural policy analyses are often concerned about the effects of the type and the size of policy instruments on (parts of) the economy. They usually neglect that timing of a policy reform can be a third choice variable for policy makers. Since many policy reforms imply irreversible costs due to aspects of commitment, the central question raised in this article is therefore: 'At what point in time should a policy reform be implemented when the reform involves irreversible costs and the future is uncertain?' The problem is approached by welfare theory and modern investment theory, and applied to Norwegian agriculture in the context of a prospective agreement on agriculture in the World Trade Organisation (WTO).

A new WTO agreement on agriculture affects domestic policy making in Norway in two ways. It reduces the freedom of policy choice, and it promotes the transparency of the size and means of the policies. The outcome of the 1995 Uruguay-round restricted the use of various policy instruments to support agriculture. It caused a major shift in Norwegian agricultural policy as quantitative import restrictions had to be replaced by tariffs. The second effect is less visible, and more difficult to assess quantitatively. The current WTO agreement caused agricultural support to be in the focus of public discussion. This has been accomplished by the use of transparent measurements of agricultural support that simplify the impenetrable jungle of policy instruments. Interest groups that are likely to have opposite interests in relation to farmers on various policy aspects (consumers want lower food prices, taxpayers desire reduced transfers to the farm sector, etc.) might have improved their relative political power.

Policy makers are supposed to have the opportunity to implement a long-term policy reform that compensates farmers for closing down the farm, or equivalently, for not start farming. Such policies are not so unusual as it might seem. In the EU and Norway, early retirement schemes and programs to buy out milk producers are put in place. The main difference is that those programs do not require farmers to close down the farm. In order to make the policy reform credible the compensation payments are considered to be irreversible once the program is in place. In addition, the total costs of the policy reform may exceed the pure compensation payments due to social costs or multiplier effects elsewhere in the economy. All this takes place in an environment of uncertainty about future conditions. Given these conditions, there exists an option to wait to implement the policy reform now that creates an opportunity cost that needs to be taken into account in the calculation of the expected net present value of the policy reform.

The theory used in this article combines traditional welfare analysis with modern investment theory under uncertainty. Dixit and Pindyck [DP] (1994) have treated the latter in detail in the case of investment decisions for firms. Recent empirical applications can be found in natural resource economics and agricultural economics.[1]

[1] See Pindyck (1999) for an application and overview in the field of environmental policies. Tegene, Wiebe, and Kuhn (1999) study farmland conversion. Dixit and Pindyck (1994) analyze price stabilization policies, while Fisher and Hanemann (1990) discuss the concept of the option value with regard to the contingent valuation method.

The paper proceeds as follows. Section 2 gives an introduction into the dynamics of investment under uncertainty and presents the theoretical model based on DP (1994). Comparative static results complete this section. One important result is that the option value provides an economic argument that supports 'opportunistic behavior' of policy makers. That is, a policy reform will be delayed if policy makers expect a future situation in which the relative political power of those who benefit from the reform increases. A description of the parameterization of the numerical model together with the results is given in section 3. Section 4 suggests possible improvements of the model, and concludes with a short discussion on the relevance of the concept of the option value for applied policy analysis.

2. Framework

A standard approach to deal with the kind of dynamic welfare analysis outlined above would be to calculate the net present value (NPV) of the policy reform proposal, with the decision criteria to implement the policy reform whenever NPV > 0. DP (1994) state three conditions under which the standard approach may lead to an incorrect result: (1) policy makers stand free in the timing of the policy reform, (2) the policy reform incurs irreversible (sunk) costs, and (3) the value of some variables is uncertain (stochastic).

Policy makers are legally given the right to decide the timing of a new policy. Sometimes they are restricted in the timing decision by laws or other (international) agreements. The degree of freedom to act, however, depends partly on the policy makers themselves as they may choose to act in advance of the adoption of new law. The policy reform discussed here is assumed not to be in conflict with either the current or a new WTO agreement, because the payments are made contingent on the farmer's decision to close down the farm (decoupled income support). Therefore, policy makers have the opportunity to postpone the policy reform.

Policy reforms in agriculture are often perpetual for reasons of predictability and credibility. In the US and the EU, for example, policy reforms have a perspective of 4-5 years. The compensation payments for closing down the farms (or not start farming) are considered to be irreversible once the policy is set into law. In addition, agricultural investments are often enduring and involve irreversible costs, too. Moreover, spillover effects may contribute to additional costs elsewhere in the economy, because agriculture is still important in remote areas in Norway. A decrease in agricultural activity may require adjustment costs to promote alternative industries, or to stabilize the population density in these areas if this is an overall policy objective. Hence, the total costs of the reform may exceed the pure compensation payments to farmers.

The prospective costs and benefits of any policy reform project are uncertain since they involve future payment streams. As will be shown below, the opportunity costs of the policy reform depend to a large extent on this kind of uncertainty.

2.1 Model formulation

Let A be a stock variable associated with agricultural activity. In general, A could represent capital, land, the number of holdings, or labor force. For the purpose of illustration, A is assumed to measure labor force. The evolution of A over time is given by:

$$\frac{dA}{dt} = N(t) - \delta A(t) \tag{1}$$

where δ is the exogenously given yearly rate at which (old) farmers leave the agricultural sector (i.e., t is measured in years). $N(t)$ approximates the number of actual successors (young farmers) per year. Empirical evidence shows that labor force in agriculture is decreasing over time. Therefore, there must always be some potential successors who do not start farming.[2] $N(t)$ is assumed to be the control variable that can be governed by policy makers through the policy reform.

Consider an ever-lasting policy that grants potential entrants into agriculture a fixed payment provided that they (a) do not take over the farm and (b) no longer use the resources on the farm for farming activities. Implemented at $t = s$ the policy reduces the number of actual entrants prior to the reform, $N_0(s)$, once and for all to some value $N_1(s)$. The impact of the policy reform at any $r \geq s$ is given by $[N_0(r) - N_1(r)]$.

The flow of benefits and costs associated with A is defined by:

$$H(A_t, \theta_t) = bA_t - \theta_t cA_t \tag{2}$$

Parameter b is the per unit benefit of A, while c measures the per unit cost associated with A. θ is a stochastic variable representing the preference for costs relative to benefits. The formulation of $H(\bullet)$ opens for two interpretations. First, $H(\bullet)$ could be viewed as a kind of conventional social welfare function (SWF) with two interest groups; those who benefit from A, and those who loose from A. The economy could be described *as if* a central planner would maximize (2) for a given θ_t. Second, $H(\bullet)$ could be interpreted as a policy preference function (PPF) where θ_t denotes the relative political power of 'the losers' relative to 'the favored'. The existence of a central planner is denied, and the value of θ_t measures the outcome of the political process. For the purpose of the model, both interpretations are possible. Henceforth, I call θ_t the 'relative political weight' parameter for clarity.

The stochastic variable θ introduces uncertainty in the model. Its stochastic process is of particular importance. I assume that θ follows a geometric Brownian motion defined by:

$$d\theta = \alpha\theta dt + \sigma\theta dz \tag{3}$$

where α is a growth variable, σ is a variance parameter, and dz is the increment of a Wiener process. The expectation and the variance of $d\theta$ are given by: $E[d\theta] = \alpha\theta dt$, and $Var[d\theta] = \sigma^2\theta^2 dt$ (DP, 1994: 71). θ takes only non-negative values which makes it suitable to interpret θ as relative weights.

The objective of the policy makers is to choose the optimal size of the policy reform, $(N_0 - N_1)$ that maximizes expected net present social welfare W conditioned on the stochastic development of θ:

$$W = \mathsf{E}_0\left[\int_0^\infty H(\theta_t, A_t)e^{-rt}dt\right] - \mathsf{E}_0\left[K(N_1)e^{-r\tilde{T}}\right] \tag{4}$$

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[2] The formulation implies that the stock variable eventually reaches zero. Implications of this issue are discussed in section 4.

subject to the evolution of A given by (1). $E_0[\bullet]$ denotes the expectation based on the information at time $t = 0$. The first term represents the expected value of the flow of A at time $t = 0$ discounted at discount rate r, and the second term denotes the expected discounted value of the costs of implementing the policy reform at the (uncertain) time of implementation $\widetilde{T}$.

The policy problem compares to an optimal stopping problem with a binary choice for the policy makers (Pindyck, 1999; DP, 1994): Continue the current policy with $N = N_0$, or adopt a policy reform that leads to $N_1 \leq N_0$. Since θ is the only stochastic variable, the choice depends eventually on the evolution of θ. Intuitively, there will be some point of indifference between continuing the current policy and adopting the new policy. Let θ^* denote this critical value of θ. Continuation will be optimal for all for $\theta \leq \theta^*$, and adoption of the policy reform will be optimal for all $\theta \geq \theta^*$. This decision criteria follows from the fact that the net benefit of implementing the reform is convex in θ which in turn follows from (7), (8), and (10) below.

The formulation of the decision problem exhibits close similarities to actual policy decision-making processes. Politicians are influenced in their policy choices by polls and other methods revealing public opinion. In this model, politicians are implicitly supposed to continuously reveal the public opinion (i.e., the actual value of θ) and to implement the policy reform once the public opinion has shifted in favor for policy reform (i.e., $\theta \geq \theta^*$).

Let $W^C(\theta,A)$ and $W^R(\theta,A)$ denote the present value functions for the continuation of the current policy and the adoption of the policy reform (excluding the costs of policy reform), respectively. The optimal stopping problem can be defined as follows:

$$W(\theta,t) = max\left\{H^C(\theta,t) + \frac{1}{1+r\,dt}\mathsf{E}\left[W^C(\theta+d\theta,t+dt|\theta)\right]; H^R(\theta,t) + \frac{1}{1+r\,dt}\left(\mathsf{E}\left[W^R(\theta+d\theta,t+dt|\theta)\right] - K(N_1)\right)\right\} \quad (5)$$

where $H^C(\theta,t)$ represents the payoff function at N_0, and $H^R(\theta,t)$ denotes the payoff function at N_1. Note that $W(\theta,t)$ is a Bellman equation based on the principle of splitting up the profit in the immediate period and in the continuation value. Given the first period decision, the remaining choices are assumed to be chosen optimally (DP, 1994: 100).

In the continuation region, the first term will be greater than the second term, while the opposite holds in the adoption region. Using Ito's Lemma to get rid of the expectations and disregarding the cost term $K(N_1)$) for a moment, (6) is valid in the continuation region, while (7) is valid in the adoption region (DP 1994:109):

$$rW^C = (bA - c\theta A) + (N_0 - \delta A)\frac{\partial W^C}{\partial A} + \alpha\theta\frac{\partial W^C}{\partial \theta} + \frac{1}{2}\sigma^2\theta^2\frac{\partial^2 W^C}{\partial \theta^2} \quad (6)$$

$$rW^R = (bA - c\theta A) + (N_1 - \delta A)\frac{\partial W^R}{\partial A} + \alpha\theta\frac{\partial W^R}{\partial \theta} + \frac{1}{2}\sigma^2\theta^2\frac{\partial^2 W^R}{\partial \theta^2} \quad (7)$$

The only difference between the two functions is the level of N, i.e., the number of entrants into agriculture in each period. The solution of the differential equations (6) and (7) is given by:

$$W^C = D\theta^\beta + \left(\frac{b}{r+\delta} - \frac{c\theta}{r+\delta-\alpha}\right)A + \left(\frac{b}{r(r+\delta)} - \frac{c\theta}{(r-\alpha)(r+\delta-\alpha)}\right)N_0 \quad (8)$$

$$W^R = \left(\frac{b}{r+\delta} - \frac{c\theta}{r+\delta-\alpha}\right)A + \left(\frac{b}{r(r+\delta)} - \frac{c\theta}{(r-\alpha)(r+\delta-\alpha)}\right)N_1 \quad (9)$$

D is a constant to be determined as part of the solution, while β is given by (DP, 1994: 415):

$$\beta = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}} > 1 \quad (10)$$

Parameter β is crucial for the concept of the option value. As equations (20) and (21) below show β drives a wedge between θ^* of a project calculated with the option value and θ^* of a project calculated without the option value. Therefore, β will be called the 'wedge' parameter. An increase in uncertainty by raising α and/or σ^2, reduces the value of β, but (according to (20) and (21) below) increases the wedge. In other words, the greater uncertainty the greater the error, which is made in the calculation of an NPV disregarding the option value.

The term $D\theta^\beta$ represents the value of the option to adopt the policy reform in the future, or equivalently, the cost of giving up the opportunity to wait.

The costs of adopting the policy reform, $K(N_1)$, are assumed to be quadratic in $(N_0\text{-}N_1)$:

$$K(N_1) = k_0 + k_1(N_0 - N_1) + k_2(N_0 - N_1)^2 \quad (11)$$

This is a clear simplification, even if the costs can be expected to be convex in $(N_0\text{-}N_1)$ because costs may increase non-linear as one departs from the current policy. The particular choice of the quadratic functional form is merely an approximation of a more general convex function.

There are four variables to be determined: N^*, β, D and θ^*. N^* will be a function of θ: $N^* = N_1(\theta^*)$. Hence, we need three independent equations:

$$W^C(0, A) = 0 \quad (12)$$

$$W^C(\theta^*, A) = W^R(\theta^*, A) - K(N) \quad (13)$$

$$\frac{\partial W^C(\theta^*, A)}{\partial \theta} = \frac{\partial W^R(\theta^*, A)}{\partial \theta} - \frac{\partial K(N)}{\partial \theta} \quad (14)$$

(12) has already been used in the calculation of β in (10). It reflects the fact that θ remains at zero forever, once it has reached zero. This follows directly from the definition of the geometric Brownian motion in (3) since $d\theta = 0$ for $\theta = 0$. (13) is the 'value-matching' condition. The critical value of θ, θ^*, is given at the point where the net present value of continuing the current policy equals the net present value of adopting the policy reform. (14) is the 'smooth-pasting' condition and requires the slopes of the two net present value functions to be equal at θ^*. Therefore, the value functions must be continuous in θ^* (Pindyck, 1999: 8).

Before determining D and θ^*, I consider N^*. N^* is chosen so as to maximize the net present value of the policy reform at the time of adoption:

$$\max_{N_1}\left[W^R\left(N_1;\theta^*,A\right)-K\left(N\right)\right]=\left(\frac{b}{r+\delta}-\frac{c\theta^*}{r+\delta-\alpha}\right)A+\left(\frac{b}{r\left(r+\delta\right)}-\frac{c\theta^*}{\left(r-\alpha\right)\left(r+\delta-\alpha\right)}\right)N_1 \qquad (15)$$
$$-k_0-k_1\left(N_0-N_1\right)-k_2\left(N_0-N_1\right)^2$$

The first order condition becomes:

$$N^*=N_1=N_0+\frac{b}{2k_2r\left(r+\delta\right)}-\frac{c\theta^*}{2k_2\left(r-\alpha\right)\left(r+\delta-\alpha\right)}+\frac{k_1}{2k_2} \qquad (16)$$

Substituting (16) back into (13) and (14), we get the following solution for θ^* and D:

$$\theta^*=\frac{p}{c\left(\beta-2\right)}\left[\left(\frac{b}{r\left(r+\delta\right)}+k_1\right)\left(\beta-1\right)+\sqrt{k_0k_2 4\beta\left(\beta-2\right)+\left(\frac{b}{r\left(r+\delta\right)}+k_1\right)^2}\right] \qquad (17)$$

$$D=\frac{c}{p2k_2\beta}\left[\frac{c\left(\theta^*\right)^{2-\beta}}{p}-\left(\frac{b}{r\left(r+\delta\right)}+k_1\right)\left(\theta^*\right)^{1-\beta}\right] \qquad (18)$$

where $p = (r-\alpha)(r+\delta-\alpha)$.

Note that the solution is given by the largest root of the quadratic equation behind (17), since $(W^R - W^C - K)$ is convex in θ^*. Considering (17), $\beta > 2$ (where β is the 'wedge parameter') is required in order to get a valid solution. If $\beta < 2$, (17) and (18) are no longer valid. Instead, $N^* = 0$, and the new critical value θ^* can be calculated using (12) – (14) as before. Also, by definition, (17) is only true in the range $0 \le N^* \le N_0$. For other values of N^*, (17) and (18) do no longer apply. In these cases we get corner solutions with either $N^* = 0$ (if N^* from (16) < 0) or $N^* = N_0$ (if N^* from (16) > N_0). The corresponding critical value θ^* can be calculated as before.

To conclude this section θ^* in (17) is compared with the critical value of θ if the conventional concept of the NPV had been used. In the latter case, $D\theta^\beta = 0$, and the critical value of θ, θ^*_{conv}, is defined by (from (13)):

$$\left(\frac{b}{r(r+\delta)}-\frac{c\theta^*_{conv}}{(r-\alpha)(r+\delta-\alpha)}\right)N_0=\left(\frac{b}{r(r+\delta)}-\frac{c\theta^*_{conv}}{(r-\alpha)(r+\delta-\alpha)}\right)N_1-k_0-k_1\left(N_0-N_1\right)-k_2\left(N_0-N_1\right)^2$$

$$\Leftrightarrow \theta^*_{conv}=\frac{p}{c}\left[\left(\frac{b}{r\left(r+\delta\right)}+k_1\right)+\sqrt{4k_0k_2}\right] \qquad (19)$$

Let θ^*_{adj} denote θ^* from (17), one gets:

$$\theta^*_{adj}=\frac{\left(\beta-1\right)\left(\frac{b}{r\left(r+\delta\right)}+k_1\right)+\sqrt{4k_0k_2\beta\left(\beta-2\right)+\left(\frac{b}{r\left(r+\delta\right)}+k_1\right)^2}}{\left(\beta-2\right)\left(\left(\frac{b}{r\left(r+\delta\right)}+k_1\right)+\sqrt{4k_0k_2}\right)}\theta^*_{conv} \qquad (20)$$

The opportunity to delay the policy reform drives a wedge between the critical values. The wedge is positive as long as $\beta > 2$. In the special case when fixed costs are zero, the wedge simplifies to:

$$\theta^*_{adj} = \frac{\beta}{\beta - 2}\theta^*_{conv} \tag{21}$$

An increase in the variance rate σ, the growth rate α, and in the discount rate r all increase the wedge in (21). The greater uncertainty, the greater the error that is made if the NPV is not adjusted for the opportunity costs of giving up the option to wait. The cost parameters increase the wedge between θ^*_{adj} and θ^*_{conv} only if fixed costs are positive.

3. Numerical application

The analytical results in the previous section indicate only the direction of changes in parameters on the design of policy reform, but not their strength. Some analytical results are ambiguous or difficult to obtain. In this respect, the presentation of a numerical application serves two different objectives. First, it indicates the strength of parameters on the design of the policy reform, and second, it provides an example of how the theory can be applied to real world policy analysis.

3.1 Assumptions and choice of parameters

The availability of appropriate data for that kind of policy analysis for Norwegian agriculture is very limited. Due to a lack of econometric estimates, it has been necessary to construct some parameter values rather intuitively. Most of the data are taken from the National Account of Agriculture provided by the NILF (Budsjettnemnda for jordbruket [BFJ] var. iss.), and the PSE database of the OECD (OECD 1999). The data to calibrate the supply function and the demand function are taken from the PSE-database for the year 1997

Let a single composite agricultural product represent Norwegian agriculture. Furthermore, assume linear functional forms. Although a simplification, it is rather the rule than the exception in applied welfare analysis in agricultural economics (e.g., Bullock, 1996; Garcia and Lothe, 1996; Kola, 1993; and Salhofer, 1996). The supply function and the demand function take the following form, respectively:

$$Q^s = s_0 + s_1 P^s \tag{22}$$

$$Q^d = d_0 + d_1 P^d \tag{23}$$

where $Q^s(Q^d)$ is the quantity supplied (demanded), and $P^s(P^d)$ is the prevailing market price. I require $s_1 > 0$, and $d_1 < 0$ so as to guarantee the usual upward (downward) sloping supply (demand) curve.

I further assume that current Norwegian agricultural policy can be described by two policy instruments: a per unit tariff (T) and a per unit price support (X). This classification facilitates the use of the PSE-database, and follows a common methodology to categorize agricultural support into a domestic support component financed by taxpayers and a market price support component financed by consumers. Although Norwegian agricultural policy reform has turned direct price subsidies into direct payments based on input use in recent years, direct payments are still tied to actual input use and hence strong related to actual production.

The demand elasticity, $\eta = -.35$, is taken from Rickertsen (1994: 52). The construction of the supply elasticity is based on two intuitive assumptions. First, I require $s_0 \leq 0$ so as to indicate that there will be no production if the product price falls below zero. This assumption can be justified under the long-term perspective taken in the model. Second, I require the world market price to be $P_{WM} \geq -s_0/s_1$. This assumption implies that the quantity supplied will be positive even in the case of non-intervention. Even if this assumption may not hold for single products, it can be assumed to hold for the composite agricultural product. Clearly, the composition of the agricultural product may change considerably between the base year and a non-intervention scenario. This is a serious objection against the chosen method. Joint production which is typical for Norwegian agriculture (e.g., milk and beef, grains and pork), however will tend to stabilize the composition.

Both assumptions together with the specific functional forms of the supply curve constrain the range of the elasticity of supply, ε: $1 \leq \varepsilon \leq P^s/(P^s - P_{WM})$. I choose the average of the two limits which gives $\varepsilon = 1.257$. Garcia and Lothe (1996) find a long run elasticity of supply of .34 for the Norwegian milk sector in the period 1959-1982. Kola (1993) estimates a long run elasticity of supply of .79 for the Finnish milk sector. Henrichsmeyer and Witzke (1991: 291) report a range of the elasticity of supply for the German milk sector between .5 and 2.0.

The benefits b of the stock variable A given some policy Y are measured as the per unit (of A) difference in producer surplus under the current policy and producer surplus under non-intervention:

$$b = \frac{PS(Y) - PS(0)}{A} \tag{24}$$

Similarly, the costs of the current policy c are measured as the difference in consumer/taxpayer surplus under policy Y and consumer/taxpayer surplus under non-intervention:

$$c = \frac{CS(Y) - CS(0)}{A} + \frac{TX(Y) - TX(0)}{A} \tag{25}$$

The non-intervention outcome is merely taken as a reference point, and not as a target of policy reform. As usual, producer (consumer) surplus is measured as the geometric area above (below) the supply (demand) curve and below (above) the respective price line. The taxpayer costs consists of two terms: Direct price support, which applies to all domestic supply, and export subsidies required to dispose (possible) domestic excess supply. The assumption of linear functional forms simplifies the surplus calculations considerably:

$$PS(Y) - PS(0) = \frac{1}{2}\left(P_Y{}^s + \frac{1-\varepsilon}{\varepsilon} P_{97}{}^s\right) Q^s\left(P_Y{}^s\right) - \frac{1}{2}\left(P_{WM} + \frac{1-\varepsilon}{\varepsilon} P_{97}{}^s\right) Q^s\left(P_{WM}\right) \tag{26}$$

$$CS(Y) - CS(0) = \frac{1}{2}\left(-\frac{1-\eta}{\eta} P_{97}{}^d - P_Y{}^d\right) Q^d\left(P_Y{}^d\right) - \frac{1}{2}\left(-\frac{1-\eta}{\eta} P_{97}{}^d - P_{WM}\right) Q^d\left(P_{WM}\right) \tag{27}$$

$$TX(Y) - TX(0) = XQ_Y{}^s\left(P_Y{}^s\right) + max\left\{Q^s\left(P_Y{}^s\right) - Q^d\left(P_Y{}^d\right), 0\right\}\left(P_Y{}^d - P_{WM}\right) \qquad (28)$$

The direct effects of the results of a new WTO agreement are stipulated by reducing the tariff and the price support with 25% each, while P_{WM} remains unchanged. The 1995 Uruguay-round agreement required *inter alia* a reduction of tariff equivalents by 36% on average (at least 15% for each tariff item), and a reduction of domestic support by 20%. The prospective WTO agreement assumed here can be seen as a moderate continuation of that agreement. Other outcomes are, of course, also possible. The per unit benefits (b) and per unit costs (c) of the current policy and under the WTO scenario are presented in table 1. The amount of labor force in the Norwegian agricultural sector was (A_{1997}=) 85,800 man-years in 1997 (BFJ, 1998: 23).

Table 1. Annual benefits and costs per man-year in agriculture (NOK pr man-year)

	Current policy	WTO
Benefits (b)	127,208	78,477
Costs (c)	223,582	147,463
Net benefits	-96,374	-68,986

The net benefits of agricultural activity are on average estimated to be –96,374 NOK per man-year. This result suggests that abolishing agricultural activity in Noway would be welfare improving. The result is not surprising given the perspective of the model, which assumes government intervention to create deadweight losses.

The rate of exogenous exit from agriculture δ is calculated from (1) under the assumption of 30 years between intergenerational transfer. The costs of the policy reform are a main variable of the model, but difficult to estimate considering the lack of data on similar reforms in Norwegian agricultural policy. I specify two different cost functions, K^H and K^L, to span out a kind of opportunity set. Farmers are compensated for their loss in producer surplus when closing down the farm under the current policy. The compensation is thus assumed to be independent from policy changes. In particular, a farmer who shuts down after the (possible) implementation of a new WTO agreement is ‘overcompensated’ because producer surplus under WTO conditions is lower than under the current policy.

The difference of the two cost functions lies in the size of the additional costs that could be generated by sunk investments in the farm sector or multiplier effects elsewhere in the economy. In cost function K^H the total costs exceed the pure compensation payments considerably. The parameters are chosen such that the share of the linear costs is lower than 10% for 85% of the range of $(N_0 - N_1)$. Cost function K^L aims at representing a situation in which the reform can be achieved with lower additional costs. For this cost function, the share of the compensation payments is greater than 50% within the entire range of $(N_0 - N_1)$. The cost functions are defined as follows (mill. NOK):

$$K^H = 5 + 3.873\ (N_0 - N_1) + .01\ (N_0 - N_1)^2 \qquad (29)$$

$$K^L = .5 + 3.873\ (N_0 - N_1) + .001\ (N_0 - N_1)^2 \qquad (30)$$

The net present value of a removal of all entrants (i.e., $N_1 = 0$) becomes 1,926 mill. NOK under the low cost alternative, and 92,879 mill. NOK under the high cost alternative.

No empirical estimates are available for the evolution of θ over time. I assume two stochastic evolutions of θ. The first alternative ('Non-WTO') aims at describing a situation in which the relative weights of the interest groups are more or less constant. In this alternative, the parameter values are set at $\alpha = 0$, and $\sigma = .01$. The second alternative ('WTO') captures the effect of a new WTO agreement on the development of θ. Increased domestic focus on agricultural policy issues is considered to result in a positive drift rate ($\alpha = .0001$) and higher uncertainty ($\sigma = .05$) compared to the 'Non-WTO' alternative. The 'WTO' alternative is based on the assumption that the new WTO agreement reinforces transparency and public focus on Norwegian agricultural policy, which in turn leads to a shift in the relative weights in the favor of consumers and taxpayers.

One way to obtain empirical estimates for the evolution of θ could be to run a series of PPF-studies for consecutive time periods. Oehmke and Yao (1994) provide a model in which they get PPF weights for two different years. Such an analysis would, however, constitute a research project on its own.

3.2 Results

The main results of the numerical calculations are summarized in table 2. The scenarios differ in their assumptions on the policy regime, the stochastic evolution of θ, and the cost function. The scenarios are constructed so as to single out the pure effect of the three components on the critical value θ^* and the level of reduction ($N_0 - N_1$).

Table 2. Critical value θ^* and size of policy reform ($N_0 - N_1$) for different scenarios

Scenario				
Policy regime	Evolution of θ	Cost function	θ^*	$N_0 - N_1$
Current policy	Non-WTO	High	.676	175
Current policy	Non-WTO	Low	.675	1,722
Current policy	WTO	High	.933	1,140
Current policy	WTO	Low	.706	2,860
WTO	Non-WTO	High	.669	117
WTO	Non-WTO	Low	.667	1,122
WTO	WTO	High	.942	743
WTO	WTO	Low	.741	2,860

The two first scenarios reported in table 2 ('Current policy, Non-WTO, •') represent a situation in which there is little uncertainty about the evolution of θ. Depending on the cost alternative, the policy reform should be adopted when θ reaches a critical value of .676 (high cost alternative), and .675 (low cost alternative). Entry into agriculture should be permanently reduced by 175 and 1,722 man-years per year, respectively.

The following two scenarios ('Current policy, WTO, •') capture very much of today's situation in which the current policy still prevails, but the new WTO negotiations increase the uncertainty about the evolution of the relative political weights. θ^* increases and – depending on the cost alternative – the reduction of the entries into agriculture becomes considerably larger. In the second of these scenarios ('Current policy, WTO, Low'), the critical value θ^* is in fact a corner solution with $N_1 = 0$. Accordingly, the policy reform should induce all potential entrants into agriculture to close down their farms.

The last four scenarios illustrate the effects of a new WTO agreement on the optimal timing and design of the policy reform. The pure effect of a change in the expected evolution of θ is unambiguous with respect to the optimal timing and size of the policy reform. Increased uncertainty about the relative weight (i.e., switching from 'Non-WTO' to 'WTO') delays the reform and boosts its size. The pure effect of a change in the policy regime (i.e., switching from 'Current policy' to 'WTO') is ambiguous with respect to the optimal timing of the policy reform, but reduces the size unambiguously. The reason for the ambiguity with respect to the timing decision is that a switch from the current policy to a WTO scenario reduces both benefits and costs. A reduction in benefits reduces θ^*, but a reduction in costs increases θ^*.

Although the results reported in table 2 are based on a numerical application and not on empirical estimates, it might be of interest to compare them with empirical studies. According to van der Zee (1997), PPF studies often reveal that the relative weights of agricultural producers are 'considerably higher' (p. 106) than the weights of taxpayers and consumers. Given the high levels of support to Norwegian agriculture, one should expect a similar result for Norway. In Oehmke and Yao (1994: 637), the political weight of producers relative to consumers is 3.11 in 1977 and 1.55 in 1984. Even the lowest of these two values compares roughly to a value of θ of (1/1.55 =) 0.645. They are still lower than all the critical values of θ^* shown in table 2. In other words and according to the numerical application, if the actual value of $1/\theta$ were around 1.5 in Norway, there would be no reason to implement the policy reform under whatsoever scenario today.

A closer look reveals the importance of the option value to wait for the calculation of the net present value of the policy reform. Figure 1 illustrates the relationship between the adjusted NPV and the conventional NPV together with the option value of the policy reform for the scenario ('WTO, WTO, High'). The critical value of θ^* for the adjusted NPV is .942, while the critical value for the conventional NPV is .625. The wedge for the two critical values of θ^* is 1.545 from (20). The error becomes more than 50%.

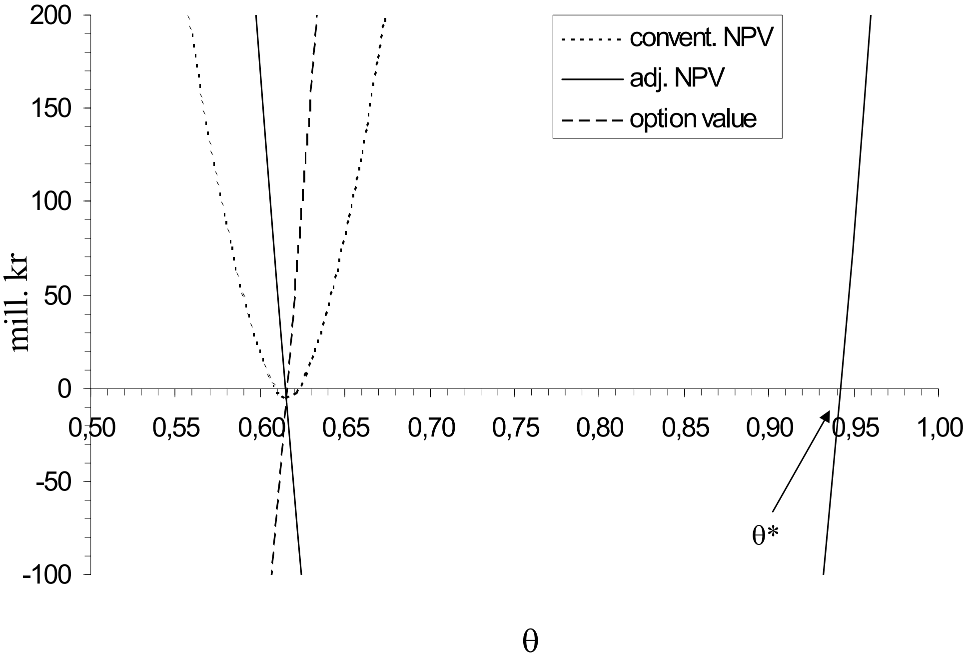

Figure 1. NPV and option value of policy reform for scenario ('WTO, WTO, High') (read ',' as '.')

Welfare analysis that uses the conventional NPV would find it Pareto-improving to adopt of the policy reform for all $\theta > .625$. Suppose the actual θ to be in the range $\theta_{act} \in (.625, .942)$. The suggestion to adopt the policy reform based on this welfare analysis would be wrong since it does not account for the costs of giving up the opportunity to wait. It can be concluded that the growing internationalization of Norwegian agriculture, here represented by a prospective WTO-agreement, makes it necessary to be more careful when assessing the net present value of a policy reform.

4. Conclusions and possible extensions

This article presents a unified treatment of how to integrate the opportunity costs of implementing a policy reform (i.e., its option value) in a traditional welfare analysis. The timing and size of a policy reform for Norwegian agriculture in advance of a prospective WTO agreement is chosen as a case study to illustrate the theory. The theoretical results show that the existence of the option value can explain why conventional welfare analyses that do not account for these additional opportunity costs may find current policies to be Pareto-inferior.

Several extensions of the model are expected to improve upon the results. First, the formulation of the model presupposes that the stock variable eventually reaches zero. Independent from any policy choice, at some point in time, there will be no farmers left. This is a very strong assumption. One might argue that there exists a socially desirable level of agricultural activity. This possibility could be captured in the model by relating costs and benefits to the stock variable. Benefits (costs) could become an increasing (decreasing) function of the stock variable.

Furthermore, policy reforms are seldom once and for all decisions as assumed in the model. Rather, policy makers stand usually as free to determine policies, as they stand free to implement policies. Apart from the timing and size problems, the model would have to be extended with a 'length of the reform' variable. The problem for the policy makers then becomes one of balancing flexibility concerns versus credibility (commitment) concerns. Examples from agricultural policy include the reform steps that the European Union has taken since 1992. Here, crucial questions have been, and still are, the size and the committed duration of the policy instruments.

Finally, many agricultural policies are often targeted towards the flows of agricultural products (like price subsidies or tariffs) rather than stock variables like land, labor or capital. Such an extension would require considerable changes in the structure of the model, but would probably increase its value as a tool for applied policy analysis.

It remains to discuss the relevance of the concept of the option value for applied policy analysis. The theoretical analysis and the numerical example have shown that the error made by ignoring the option value in the calculation of the NPV of a project (i.e., a policy reform) is closely related to the uncertainty about the development of the stochastic variable. The incorporation of the option value has therefore to be recommended for situations in which high uncertainty prevails. For Norwegian agriculture, this is in particular relevant for studies that analyze the impacts of a WTO agreement or EU membership. The analysis has also revealed a considerable challenge on the data side in order to conduct sound empirical studies. The lack of appropriate data remains probably the most important obstacle for a wider use of these kinds of studies, and constitutes at the same time an important challenge for future research.

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