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Faustmann and the climate☆

Michael Hoel[a], Bjart Holtsmark[b,*], Katinka Holtsmark[a]

[a] Department of Economics, University of Oslo, P.O. Box 1095, Blindern, NO-0317 Oslo, Norway
[b] Statistics Norway, P.O. Box 8131 Dep., NO-0033 Oslo, Norway

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ABSTRACT

The paper presents an adjusted Faustmann Rule for optimal harvest of a forest when there is a social cost of carbon emissions. The theoretical framework takes account of the dynamics and interactions of forests' multiple carbon pools and assumes an infinite time horizon. Our paper provides a theoretical foundation for numerical model studies that have found that a social cost of carbon implies longer optimal rotation periods and that if the social cost of carbon exceeds a certain threshold value the forest should not be harvested. At the same time we show that it could be a net social benefit from harvesting even if the commercial profit from harvest is negative. If that is the case, the optimal harvest age is decreasing in the social cost of carbon.

Introduction

There has been extensive research on the question of what is optimal forest management when there is a social cost of carbon emissions to the atmosphere. A broadly accepted conclusion from this

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* Corresponding author. Tel.: +47 98836198; fax: +47 21094963.
E-mail addresses: mihoel@econ.uio.no (M. Hoel), bjart.holtsmark@ssb.no, bjj@ssb.no (B. Holtsmark), k.k.holtsmark@econ.uio.no (K. Holtsmark).

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literature is that a social cost of carbon emissions should lead to longer rotation periods and that if the social cost of carbon exceeds a certain level, the considered stand should not be harvested, see for example Asante and Armstrong (2012), Asante et al. (2011), Daigneault et al. (2010), Gutrich and Howarth (2007), Kötke and Dieter (2010), Kaipainen et al. (2004), Price and Willis (2011), Pukkala (2011), Raymer et al. (2011), Farzin and Tahvonen (1996), Tahvonen (1995), Tahvonen et al. (2010), and van Kooten et al. (1995).

While most contributions to this strand of the literature have been based on numerical simulation models, our main contribution is to analyze the issue theoretically with less restrictive assumptions than earlier theoretical studies. In addition, we illustrate the theoretical results with numerical examples. We will show that our less restrictive assumptions turn out to be important for the conclusions.

With regard to theoretical studies of the question of how a social cost of carbon should influence forest management, van Kooten et al. (1995) represent to our knowledge the most thorough study of the issue. They applied a multi-rotation infinite time horizon model and provided an adjusted Faustmann Rule for determination of the length of the rotation period when there is a social cost of carbon emissions. However, the theoretical framework of van Kooten et al. (1995) did not incorporate the dynamics of important carbon pools as roots, stumps, tops and branches, harvest residues and naturally dead organic matter.

Asante and Armstrong (2012) is another theoretical contribution. In contrast to van Kooten et al. (1995) they included the forests' multiple carbon pools in their model. At the same time they considered a single rotation model only and their time horizon was limited to the length of the single rotation. As van Kooten et al. (1995), Asante and Armstrong (2012) found that a social cost of carbon emissions increases optimal harvest age. However, their numerical analysis indicated that incorporating the pools of dead organic matter and wood products in their model have the effect of reducing rotation age. And finally, they found that the higher are the initial stocks of carbon in dead organic matter or wood products the shorter is the optimal harvest age.

Holtsmark et al. (2013) discussed the results of Asante and Armstrong (2012) and Asante et al. (2011) and found that the surprising result that the higher are the initial stocks of carbon in dead organic matter or wood products the shorter is the optimal harvest age, was an artifact of their limited time horizon. Holtsmark et al. (2013) found that from a theoretical point of view the initial stocks of carbon in dead organic matter or wood products should not influence the harvest age. Moreover, the numerical analyses in Holtsmark et al. (2013) indicated that accounting for dead organic matter has the effect of increasing the rotation age, also in contrast to the results of Asante and Armstrong (2012) and Asante et al. (2011).

Although Holtsmark et al. (2013) applied an infinite time horizon, it presented a single rotation analysis only and presented few theoretical results. This underlines the need for a theoretical, multi-period infinite horizon analysis of the issue, which includes the dynamics of the forests' main carbon pools. Therefore, this paper presents a comprehensive theoretical analysis of the question of how a social cost of carbon should influence the length of rotation and the harvest level.

The present paper combines the multi-rotation infinite time horizon model of van Kooten et al. (1995) with the single-rotation, multiple carbon pools approach of Asante and Armstrong (2012) and Holtsmark et al. (2013). Compared to the many numerical model studies of the issue, our theoretical analysis is superior in its potential to reveal the drivers behind the obtained results. While it is generally more difficult to disentangle the important assumptions in a numerical model, our theoretical framework allows us to discuss these more thoroughly.

Our starting point is Faustmann (1849), who has been attributed a formula for determination of the length of the rotation period when a forest owner's goal is to maximize the discounted yield, see also Clark (2010), Samuelson (1976) and Scorgie and Kennedy (1996). We develop an adjusted Faustmann Rule when there is a social cost of carbon emissions, while taking into account the dynamics and interactions of the forest's multiple carbon pools. From this rule it follows if there is a positive commercial profit from harvesting and the socially optimal harvest age is finite, then the optimal harvest age is increasing in the social cost of carbon. If there is a negative commercial profit from harvesting, one cannot on theoretical basis rule out that the socially optimal rotation length is finite. If the socially optimal rotation length is finite in the case with negative commercial profit from harvesting, then the rotation length is decreasing in the size of the social cost of carbon. However, our numerical model