Essays on Resource Management: Ownership, Market Structures and Exhaustability

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Chapter 7

Summary and conclusions

7.1 Summary

This thesis is concerned with resource management. Resource management has proven to be necessary over and over in history and it will remain necessary in the future as well. For proper resource management it is important to know the current market as well as the development of the market. This makes it necessary to construct models that can describe the development of the price, stocks and amount extracted over time. The better the models the more accurate the outcome, giving a better basis for policy.

Three research questions were raised in the introduction, namely:

1. What happens to the extraction path, price path and social welfare under Nash competition when agents have different extraction costs?
2. What if renewable resources, like exhaustible resources, are confined to areas that do not physically interact with one another?
3. Is cooperation or coordination to be preferred over competition?

These questions have been investigated in the different chapters.

Chapter 2 gives the full characterization of the open-loop Nash equilibrium of a nonrenewable resource game between two types of firms with different extraction costs. Hereby it is possible to address research question number 1. It is shown that, despite difference in costs, a phase almost always exists where both types of firms are supplying simultaneously. It is of interest to see that, in contrast to a situation of perfect competition, it will not always be the case that the cheaper mines will be exploited first. This violates the Herfindahl rule and is thus also detrimental to social welfare. Furthermore, increasing competition by dividing high-cost mines among more agents can also result in social welfare losses as it can exacerbate the inefficiency when the Herfindahl rule is violated. It thereby also addresses research question 3: since

increased competition can reduce welfare, cooperation could be beneficial for social welfare. The reduction in welfare due to increased competition has implications for the cartel-versus-fringe case as well, as it cannot be guaranteed that the Herfindahl rule is not violated under this structure.

Chapter 3 takes this last point one step further. If the Herfindahl rule can be violated in the cartel-versus-fringe case, causing social welfare losses, if could even be the case that resource discoveries by the fringe could be detrimental to welfare as well. In this chapter it is shown under what conditions this is the case. Besides reductions in social welfare due to resource discoveries, it is also shown that welfare might decrease due to a decrease in extraction costs of the fringe.

Chapter 4 compares the different cartel-versus-fringe equilibria in a quantitative manner including the equilibrium described in chapter two. Notably the open-loop Nash, the open-loop Stackelberg and the closed-loop Stackelberg are compared with one another as well as with the situation of perfect competition and the situation of monopoly. The chapter thereby mainly addresses research question 3. Under realistic numbers the open-loop Nash equilibrium is often a better proxy for the mathematically complicated closed-loop Stackelberg equilibrium than the open-loop Stackelberg equilibrium. Furthermore, cartels are, as can be expected, detrimental to social welfare, however, outcomes can come close to the socially desirable outcomes. Cartels are therefore not by definition bad.

Chapter 5 places renewable resources in a global market as is customary in the non-renewable market. Instead of one resource pool there will be a second resource pool, resulting in competition in management of the resource. Hereby, a situation comparable to the non-renewable resource models in earlier chapters is created and research questions 2 and 3 are treated. Within this framework several situations have been analyzed with respect to property rights, market structures and size of the resource pool, both in autarky as well as in a common market. Several interesting results were found, such as the possibility of extinction of a stock when a common market is formed, a possible reduction in profits with an increase in market power and the increase of supply when market power is reduced.

Chapter 6 introduces dynamics in a framework of capital as well as environmental taxation in a two-country setting. Agents determine savings decisions on the basis of expectations and thereby the amount of capital available one period later. The amount of pollution is concomitantly influenced as the amount of capital is the basis for demand and thereby pollution originating from production. The amount of pollution in turn partly determines environmental

taxation, the other part is determined by the amount of transboundary pollution. Whether environmental taxation is more stringent in a competitive case or in a cooperative case, addressing research question 3, depends on the parameter values. The ambiguity comes from opposing forces. The demand for products is higher in the competitive case, yielding a higher taxation; however, the transboundary characteristic of pollution reduces the need for higher taxation. The model developed allows for the possibility of a race to the bottom without this being inevitable.

7.2 Relevance for research and policy

The introduction identified gaps in the existing literature. Furthermore, the very nature of resources can yield results that are different from common perception. This thesis aimed to bridge some of those gaps and present some insights into the effects of the nature of resources.

From a research perspective several contributions have been made. First, this thesis bridges the gap between the contributions of Loury (1986) and Lewis and Schmalensee (1980) by allowing multiple agents with two distinct extraction costs. Second, this bridge allowed building a cartel-verses-fringe game with open-loop Nash equilibrium, and thereby a quantitative overview of the different cartel-versus-fringe equilibria. Third, a renewable resource model with two separate regions is created. Lastly, a model is developed that can predict whether or not a race to the bottom will occur.

From a policy perspective several contributions are made as well. It is shown that a reduction in extraction costs can be harmful. When high-cost firms obtain a slightly better technology, reducing their extraction costs, they can obtain a higher market share, pushing the low-cost producers away. Thus extraction from low-cost mines is delayed to the advantage of high-cost mines. Therefore, a policy that is aimed at leveling the playing field by subsidizing high cost firms in an attempt to create more competition might do more harm than good.

The second policy-relevant aspect, linked to the previous point, relates to the discovery and exploitation of new oil fields. When high-cost firms find new exhaustible resource fields it can harm the welfare in the same way as before. The discovery might push extraction of the cheaper resource further into the future. Although it might seem to be beneficial to have more of a good it is not always the case[1].

The third policy-relevant aspect is related to cartels. Governments try hard to break cartels as they are considered to be detrimental to social welfare. This thesis has shown that cartels are

[1] Findings and exploitation of new oil fields will be beneficial once all low-cost mines have been exploited

not necessarily bad. Depending on the market structure and the difference in size of stock, as well as the difference in marginal extraction costs between the cartel and the fringe, the damage done to social welfare due to cartelization, as compared to a situation of perfect competition, is limited. It might even be the case that cartelization is better compared to a state where all players have some market power.

The fourth policy-relevant aspect relates to the enlargement of markets. The European Union has been and still is expanding, thereby creating an ever-increasing market by adding separate markets to one another. If property rights are not properly defined the enlargement of markets might actually cause a renewable resource pool to become extinct.

The final practical relevance of the research describes at which administrative level competition should take place where taxation is concerned. This is called for in fighting pollution in this period with large transboundary pollution. When a strict environmental policy is preferred, cooperation is not always better than competition.

The central recurring theme is that, where natural resources are concerned, standard microeconomic results do not necessarily hold. Natural resources deserve special attention in order for good policies to be developed.

7.3 Further research

The different chapters have already touched on possible future research. The gap between theory and practice has to be made smaller. Models are by definition a simplification of the world, however, in order to provide a basis for relevant policy measures they should, in the relevant areas, be as close to the world as possible. The models presented in this thesis present one step in the direction of more realistic modeling; but more steps need to be taken. We will discuss here changing demand, the embedding of natural resources into different sectors, the inclusion of uncertainty and heterogeneity of players.

Changing demand

Chapters 2-5 all used fixed demand functions for models that represent several decades. One only has to go back 30 years and compare that world with the present day world to see huge changes. The rise of the China, India and other East Asian countries, the end of the cold war, the Iraqi war and the current economic crisis. Nobody can make a justifiable claim that these events have no effect on the demand for resources. This makes an adjustment of the demand function necessary. This calls for inclusion of economic growth as well as the possibility of

events. Especially inclusion of events complicates matters, as it not only calls for stochastic modeling but will most likely also give rise to non-convexities.

Embedment of natural resources

Except for chapter six all chapters treat natural resources in isolation. Embedding goes a step further than a change in demand function. Chapter 4 already hinted at embedding. The inclusion of other sectors creates several repercussions. For example, an increase in the oil price increases the demand for biofuels, putting pressure on agricultural products. Another possible repercussion of higher prices they will lead to a search for alternatives which might, if successful, reduce the demand and hence price for oil. On top of this agents, will have expectations, complicating matters further.

Uncertainty

The events described in relation to a changing demand function are likely to be uncertain. Uncertainty is also likely to play a role in determining the stocks. A relatively simple solution would be to make scenarios; however, a known probability distribution concerning the different scenarios is needed for this, bringing with it the risk of the curse of dimension. Another possible route to take is Monte Carlo modeling.

Heterogeneity of players

Chapters 2-4 allowed for more than two players: however, not for more than two groups of players. In reality there will be a more heterogeneous distribution of agents. A similar approach to that taken in chapter 2 might work by looking at possible transitions. If it turns out that, for example, a maximum of two types of agents can produce at the same time, analytical solutions can possibly be found. If, however, it turns out that all configurations[2] are possible, it is unlikely that analytical solutions can be found and numerical modeling must take place.

The proposed future research directions are more and more unlikely to be of a purely analytical nature. This will make stochastic and numerical modelling more and more likely to occur. This should be done on the basis of a theoretical model, making sure that within a specified domain the outcomes of the numeric processes converge to a unique steady state so that policy measures can be inferred from this. Without the convergence to a unique steady state one cannot be certain that the policies recommended or applied yield the preferred outcome.

[2]A configuration is for example that players 1,2 and 4 are producing while 3, 5,..,n are not producing or 2, 4 and 5 produce while the others are not producing.