

Cassel's Contribution to the Economic Theory of Exhaustible Resources

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Introduction

The economic theory of exhaustible resources is widely regarded as having had its origins in Harold Hotelling's paper "The Economics of Exhaustible Resources" which was published in the *Journal of Political Economy* in 1931.¹ This widely held view is, however, incorrect. As has been demonstrated elsewhere, there is a significant literature stretching back at least to Adam Smith which discusses the economics of mining.² Moreover this literature sometimes emphasises the problem of increasing scarcity of mineral resources which Hotelling so elegantly analysed.

Amongst the significant contributors to this literature were Smith himself, Ricardo, Henry Carey, J.S. Mill, W.R. Sorley, Marshall, Lewis Gray and Gustav Cassel. While a significant literature dealing with Hotelling's paper has emerged in the past 20 years, there has also recently been a small number of contributions dealing with the work of his predecessors.³ These contributions have, in most cases, dealt with authors whose work was sympathetic to the North American conservation movement which was active early this century:

Hotelling's Predecessors

Of Hotelling's predecessors who are discussed in this literature, by far the most cited is Lewis Gray who produced two papers in quick succession in 1913 and 1914.⁴ Gray, who was a prominent conservationist, was the first economist to analyse thoroughly the idea that micro-economic decision making in the mine differed from that on the farm since miners, unlike farmers, were dealing with the exploitation of a finite, exhaustible resource. Whereas, for the farmer, production of output today does not normally diminish the capacity to produce tomorrow, in the case of the miner, today's and tomorrow's production are antagonistic. This fundamental difference will lead to differing short-run optimisation decisions in the mine and on the farm.

Gray's capacity to explain how decision making in the mine differed from that on the farm, has led a number of authors to argue that his contribution to the literature is of similar significance to Harold Hotelling's. It should be emphasised, however, that Gray's contribution was very different in nature from Hotelling's. While Hotelling was concerned primarily with the long-term tendency for mineral rents, and thus mineral prices, to rise, Gray concentrated on short-run production decisions in the mine. When he did consider the long-run, Gray assumed that price remained constant over time and that, furthermore, it contained no rent or royalty component, and was thus equal to the marginal cost of extraction.

The emphasis which the literature dealing with Hotelling's immediate predecessors gives to work such as Gray's which was produced as a response to the first North American conservation movement is, in many ways, unfortunate since it fails to deal with the views of a number of authors whose contemporaneous contributions were much more optimistic. For example, F.W. Taussig whose *Principles* was, in many respects, the North American equivalent of Marshall's work of the same name, took a highly optimistic view of the future availability of mineral resources. Thus in the first (1911) edition of this work, he argued that increasing return was likely to occur on the extensive margin in mining and that "...mankind may look forward, for long ages to come, to an increase rather than to a diminution of its available mineral resources."⁵

Writing at much the same time as Lewis Gray and Taussig, the Swedish economist Gustav Cassel also took an optimistic view of the future availability of minerals. In his *Theory of Social Economy* which was ready for publication in 1914 but was not able to be published until after the war, he argued that long-run elasticity of supply of minerals is likely to be high.⁶ Factors which contribute to this situation include improvements in mining techniques, in transport and in processing; as well as the new-found capacity to exploit low quality ores of which there is a great abundance.

The optimism which Cassel displayed stood in marked contrast to the fundamental pessimism displayed by Gray and his peers. Amongst Hotelling's predecessors, Cassel was the last in a long line of optimists who included Adam Smith, Henry Carey and Karl Marx. While this optimism is of particular significance for the question of whether the essentially pessimistic contemporary economic theory of exhaustible resources is based on realistic assumptions about the future availability of minerals, there are particular aspects of Cassel's work which were unique and were thus of much greater significance in the context of the history of economic thought. The first of these was his capacity to come independently to many of the same novel conclusions drawn by Gray; the second was his ability to do what no other author has done - namely, to anticipate Hotelling's idea that expected future mineral scarcity will give rise to a steady increase over time in the price of mineral output.

Neither of these aspects of Cassel's contribution has been acknowledged by the authors whose recent work deals with Hotelling's predecessors. Indeed, as far as can be ascertained, Cassel has not previously been acknowledged as a contributor to the mineral economics literature. In the next section, the state of knowledge of mineral economics at the time when Cassel made his contribution will be discussed.

The State of the Art

Although Ricardo had identified a fundamental difference between exploitation of exhaustible minerals and the use of the "original and indestructible powers of the soil" for agriculture, it was John Stuart Mill who first explicitly argued that antagonism between present and future production in the mine might lead miners to consider the effect of current production on the capacity for future production from the finite contents of the mine.⁷ Although this idea was later taken up and refined by Lewis Gray, in the interregnum W.R. Sorley looked at the question of whether mineral royalties would, unlike farm rents, be earned by the marginal production unit. Arguing in the affirmative, he discussed, as the following quotation shows, the consequences of the fact that the owner of a mineral deposit will, unlike the owner of a farm, lose a possible source of future income if he allows his mine to be worked:

Hence as mines deteriorate by being worked, the landlord will only let them at a rent bearing some proportion to the amount of deterioration they suffer. Even the least fertile mine worked will pay a rent of this kind, and this rent will enter into the price of the product.⁸

It was not until Hotelling's celebrated article was published some 42 years later, however, that the consequences of this idea for the long-term progress of the price of mineral assets and mineral outputs was widely disseminated. Hotelling would argue that since mineral exploitation means resort to inferior deposits over time, high quality deposits will have a capitalised value which reflects their superiority over inferior deposits to which resort must be had at some time in the future. This capitalised value will, in order to give asset market equilibrium, rise over time at a rate equal to the rate of interest. Moreover, a rise in the value of mineral deposits over time will mean that, *cet. par.*, the price of mineral output will also rise over time.

By 1914 when Cassel had formulated his ideas regarding the nature and significance of the economics of mining, his immediate predecessors had established that mineral production may involve an antagonism between present and future production which would give rise to mineral output prices which were in excess of marginal production cost. As the remainder of this article will show, Cassel made a number of original contributions which involved significant advances in relation to the work of these predecessors.

With this brief background, it is now possible to look more closely at Cassel's contribution. Throughout the following discussion, comparison will be drawn with Gray's work since it is widely known and was formulated independently of, but at the same time as, Cassel's. The first aspect of Cassel's work to be examined is his treatment of mine rent.

The Rent of Mines

Like Gray, Cassel took up Bohm-Bawerk's idea that modern capital theory could be used to explain the way in which mine surplus could be broken down into two components: the interest on the capitalised value of the mine (akin to Ricardian rent) and the depreciation charge or royalty which reflected the diminution in the value of the mine which occurred with extraction. In contrast to Gray's argument that it

was unfruitful to maintain this distinction since, in reality, it is impossible to meaningfully differentiate between these two component parts of mine surplus, Cassel considered it appropriate that this distinction be maintained. The position which Cassel took in relation to the conceptual treatment of the rent of mines thus involved a continuation of the tradition which had been established and maintained by his predecessors Ricardo, Sorley and Marshall. Having established that the nature of mineral rent was different from that of farm rent Cassel next discussed the nature of short-run decision making in the mine.

Short-run Optimisation

By considering the effect of a decision to shorten the period over which the finite contents of the mine are won, Cassel was able to explain that in making production decisions, the mine owner-operator is faced with a trade off. While this shortening of the period will increase the present value of the contents of the mine, it will also increase the total cost of extracting these contents.

In order to make the best of this trade off, the owner-operator should reduce all income and expenditure to their present values. For example, it would be appropriate to bring production forward in time if an increase in the rate of production increases the present value of sales revenue by more than it increases the present value of costs. Optimisation will occur with an equalisation of these costs and revenues at the margin:

'Hence the mine-owner must, during the period of working, invest in his business so much capital that the final increase of the present value of the cost of labour and capital is outweighed by the final increase of the present value of the total sales which it secures.'

This novel treatment of optimisation in the mine makes it clear that short-run decision making has particular characteristics which derive from the inherent antagonism which exists between present and future production. Writing at the same time as Cassel, Gray also analysed the relevance of this antagonism for optimisation in the mine. However, he illustrated the solution by using tabular arithmetic examples which today seem crude in relation to Cassel's more neoclassical treatment. Cassel's treatment of the problem, though much more succinct than Gray's, showed far greater sophistication; yet it has not previously been acknowledged in the literature.

Having established the basic principle which governs optimisation in the mine, Cassel goes on to discuss the effects of a number of different factors upon this optimisation process. He considers the effect of a change in price of mineral output, the effect of change in the rate of interest, the effect of uncertainty, and the effect of a change in market structure from competition to monopoly.

A once and for all rise in the current and expected price of mineral output will, says Cassel, result in an increase in the present value of revenues. This will bring production forward in time since optimisation will, *cet. par.*, require an increase in the rate of production which raises the present value of costs. This outcome is precisely the same as that which Gray discovered using his tabular arithmetic examples. However, Cassel added another dimension, which Gray had overlooked,

by considering the effect of a once and for all increase in expected future price upon current price.

An expected rise in future price would, says Cassel, have the effect of reducing current production. While this is an unremarkable observation, Cassel goes on to show that this decrease in current production will have the effect of increasing current price. Thus an increase in expected future price has the effect of raising current prices so that they reflect future scarcity. Rather than prices remaining relatively constant until such time as the expected future scarcity results in a marked increase in price, they will tend to rise over time at a more regular rate.

This finding is of particular significance in the context of the evolution of the economic theory of exhaustible resources. It was the first time in the literature that an explicit link was drawn between present and future mineral prices. Furthermore, this finding foreshadowed Hotelling's later mathematical treatment of the tendency of mineral prices to rise over time.

In considering a rise in the rate of interest, Cassel, like Gray, noted that it would tilt the time profile of production towards the present since, *cet. par.*, it diminishes the value of future production vis a vis current production.

The effects of uncertainty were also considered by Cassel. He argued that increased uncertainty would be likely to increase present production because this uncertainty was likely to be associated with the likelihood of future progress in technology and the possibility of future discoveries. This position is consistent with his fundamental optimism which was mentioned in the introduction to this article. It stands in marked contrast to the pessimism which both Gray and Hotelling displayed.

Cassel again anticipated Hotelling in his treatment of the effect of monopoly power upon production decisions. Arguing that a monopolist will restrict present production he concluded, as did Hotelling, that the monopolist was, as contemporary authors have put it, 'the conservationist's friend'.

This discussion of Cassel's contribution to the economic theory of exhaustible resources reveals that, like Gray, he introduced a host of novel ideas about the way in which the economics of mining differs from the economics of other productive activities including agriculture. It also reveals that he not only made a contribution similar to that of his peer Gray, but that he also anticipated some of the findings of his successor Hotelling.

Conclusion

At the time that Cassel was formulating his analysis of decision making in the mine, it had been established that mining was different from other pursuits since, in mining, there is an inherent antagonism between present and future production. The significance of this feature for short-run decision making in the mine had, however, not previously been analysed in the literature. When viewed in this context, Cassel's contribution is very significant indeed. Its absence from the literature which has reviewed Hotelling's predecessors is perhaps explained by its having been buried deep within a volume of principles which has not recently been explored for its mineral economics content.

Although he made a number of significant contributions to the literature of

economics, including mineral economics, only a small amount of information about Cassel the economist is available. In his recent essay on Cassel, Lars Magnusson argues that he is commonly regarded as a second rate figure: a popularizer who, as a theoretical innovator, might not deserve more than a footnote in the history of economic thought.¹¹ In the light of the foregoing discussion of Cassel's contribution to the economic theory of exhaustible resources, it might be appropriate to argue, as Stigler has done of J.S. Mill, that he has displayed an originality which has been masked by the fact that he was "not trying to build a new system but only to add improvements here and there".¹² In his biographical entry in the *New Palgrave*, Bo Gustafsson has remarked that a good biography of Cassel is yet to appear.¹³ When it does, it is to be hoped that some light will be shed on the reasons for Cassel's interest in the economics of mining, and his capacity to deal so innovatively with it.

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Notes

1. H. Hotelling, "The economics of exhaustible resources", *Journal of Political Economy*, vol 39, no 2, 1931
2. T.J.C. Robinson, *Economic Theories of Exhaustible Resources*, Routledge, London, 1989
3. See, for example: P.J. Crabbe, "The contribution of L.C. Gray to the economic theory of exhaustible natural resources and its roots in the history of economic thought", *Journal of Environmental Economics and Management*, vol 10, 1983; J. Raumont, "L'homme et la destruction des ressources naturelles: la Raubwirtschaft au tournant du siècle", *Annales - économie, sociétés, civilisations*, vol. 39, no. 4, 1984; and G.A. Smith, "Natural resource economic theory of the first conservation movement (1825-1927)", *History of Political Economy*, vol. 14, 1982.
4. L.C. Gray, "The economic possibilities of conservation", *Quarterly Journal of Economics*, vol. 27, 1913, and "Rent under the Assumption of Exhaustibility", *Quarterly Journal of Economics*, vol 28, 1914
5. F.W. Taussig, *Principles of Economics*, Macmillan, New York, 1911, pp 95-96
6. G. Cassel, *The Theory of Social Economy*, translated by J. McCabe, Fisher Unwin, London, 1923
7. Robinson, *op.cit.* ch. 5 and ch. 8
8. W.R. Sorley, "Mining royalties and their effect on the iron and coal trades", *Royal Statistical Society Journal*, vol. 52, 1889, p. 78
9. Cassel, *op.cit.* p. 282
10. These aspects are discussed in Cassel, *op. cit.*, pp. 282-285
11. L. Magnusson, "Gustav Cassel, popularizer and enigmatic Walrasian", in B. Sandelin, ed., *The History of*

Swedish Economic Thought, Routledge, London, 1991, pp. 122-123

12. G.J. Stigler, "The Nature and Role of Originality in Scientific Progress", in G.J. Stigler, *Essays in the History of Economics*, University of Chicago Press, Chicago, 1965, p. 11.
13. B. Gustafsson, "Gustav Cassel" in J. Eatwell, *et al*, eds, *The New Palgrave*, Macmillan, London, 1987, vol. 1, pp. 377.

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